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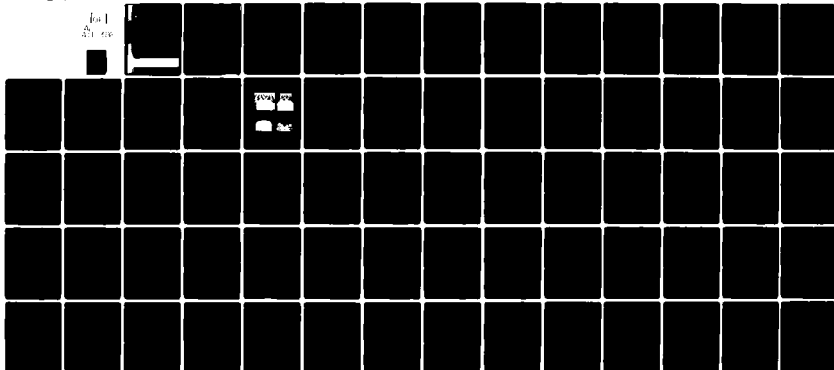
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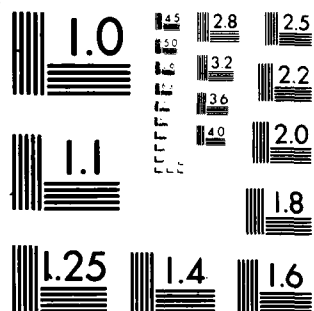
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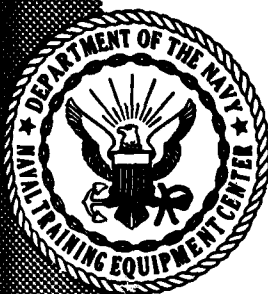
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TECHNICAL REPORT: NAVTRAEQUIPCEN 78-C-0060-5

UNCONVENTIONAL VISUAL
DISPLAYS FOR FLIGHT TRAINING

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displaying the information that is necessary to support learning of the tasks.

Four different visual displays were evaluated for their effectiveness in the acquisition of flight tasks in a simulator. The control condition had a wide field-of-view, a horizon and a checkerboard ground plane that obeyed laws of motion and perspective. The experimental displays were: (1) a narrow field-of-view with horizon and checkerboard ground plane; (2) an outside viewpoint of an aircraft; and (3) a display that consisted only of normal flight instruments. Flight-naive subjects were taught to fly straight-and-level for twenty trials with either the control or one of the experimental displays and then tested for twenty trials on the control display. Training, transfer, and differential transfer performance was examined.

Pre-training with the experimental displays resulted in substantial transfer savings to the control display. The differential transfer analyses did not show a clear advantage for any of the displays. The hypothesis that control skills can be learned using representations of the essential information that depart radically from the form found in natural scenes was supported by the results. The results also suggest that perceptual learning may occur quickly relative to control skill learning. Field-of-view did not importantly affect training or transfer performance of the Straight-and-Level task. In particular, there was no evident advantage of using a wide field-of-view for training this task.

Unconventional visual displays show promise as cost effective means for teaching some flight skills. Research on optimizing visual displays for flight training need not be restricted to conventional out-of-cockpit scenes. It is possible that unconventional displays might prove to be superior to conventional displays on a time-to-train as well as a cost basis.

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From the Canyon Research Group, Inc., Daniel Westra advised on the experimental design and Brian Nelson and Daniel Sheppard assisted with data collection and analysis.

Jack Davis and Karen Thomley of the University of Central Florida (Contract N61339-78-C-0156) also assisted with data collection and analysis.

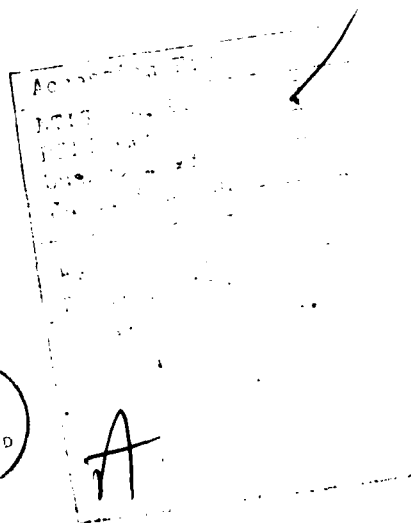


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SECTION I

INTRODUCTION

Ground-based flight simulators are used extensively to teach basic and advanced flight skills. Simulators designed to teach contact flight tasks (tasks requiring vision outside the cockpit) are equipped with visual display systems that provide the student with a view of the simulated world. These displays can produce fairly realistic scenes that obey the laws of perspective and depict natural and man-made objects similar to those encountered when flying in the real world. Most often this is accomplished by means of computer image generation (CIG) systems, although actual scale models are sometimes preferred when great amounts of detail are considered essential.

Modern visual systems are usually expensive, especially when high detail and large fields-of-view are required. Designers and buyers of military flight trainers normally assume that they should depict the world as faithfully and with as much detail as possible. They settle for less than what the state-of-the-art can provide only when forced to by economic considerations. Some, however, have questioned the extent to which such systems are necessary and cost-effective for teaching certain contact flying skills (Caro, 1977; Semple, Hennessy, Sanders, Cross, Beith, & McCauley, 1981). Caro (1977) has suggested that any means of providing the necessary information is likely to produce positive transfer for certain basic flight objectives. For example instrument flight training shows positive transfer to basic contact flight (Caro, Isley & Jolley, 1975), and landing skills learned in a simulator with a simple visual display consisting of a runway outline and a horizon line can be transferred to the aircraft (Payne, Dougherty, Hasler, Skeen, Brown & Williams, 1954).

Airplanes were used successfully as flight trainers before flight simulators existed. As their name suggests, simulators were viewed initially as substitutes for airplanes. As such, it was natural to assume that they would be used in much the same way as airplanes were used to train. The belief that a simulator offers the potential to depart radically from traditional flight instruction techniques, and that full fidelity may not only be unnecessary but counterproductive in some cases, is still decidedly a minority opinion. Acceptance of the idea that simulators can be much more than airplane substitutes has been slow to come, partly because experiments to explore this concept have been infrequent. Certainly there are meager theory and data to guide development of special training techniques and displays that exploit deliberate departures from full fidelity.

This report describes a first step in a line of research to explore the training usefulness of what we will call unconventional displays, that might enhance the effectiveness of ground-based training devices to teach certain flight skills. The concept of unconventional displays is discussed below, as part of the broader topic of image alteration procedures.

VISUAL IMAGE ALTERATION

Visual image alteration is the global term used here to describe changes to a CIG data base that result in a displayed scene that is less like what would commonly be considered a natural, real-world scene. While a scene generated with today's real-time CIG technology would seldom be mistaken for a photograph of a piece of terrain, image alteration results in changes that would make such a mistake even less likely.

There are several kinds of reasons for believing that image alteration can be useful for some training applications. These reasons are briefly described below, according to whether the altered display is considered to be conventional (either enhanced or degraded) or unconventional.

ENHANCED DISPLAYS. CIG scenes can be enhanced by the addition of objects, patterns, colors, etc. that are unlike those encountered in the real world. This might be done either to help the student make better sense of what he is seeing when flying the simulator, or to help him make better sense of what he will later see when flying the airplane.

The first purpose involves compensating for CIG deficiencies that may inhibit or totally prevent learning of the task. It is probably the most common reason for enhancement, and is behind a variety of alteration techniques seen in today's simulators. For example, pilots often complain about the lack of surface texture when trying to fly close to the ground. Regular checkerboard patterns are sometimes overlaid onto the terrain, to improve perception of its shape and orientation relative to the observer. In a similar vein, vertical objects are sometimes added to improve the observer's judgment of altitude (Buckland, Edwards & Stephens, 1981). Although the checkers and the vertical objects may make the scene look more artificial, they make the simulator more flyable at low altitudes, and therefore more useful as a trainer for that task.

The second purpose of enhancement involves adding cues to help the student learn to interpret the real-world scene. For instance, students often have trouble judging whether they are above or below glideslope when approaching a runway, because they don't know what a runway should look like at various distances and altitudes from it. Lintern (1980) augmented a runway with artificial objects early in training, and later removed them as the student progressed. Students trained with such a display performed better in the aircraft than those trained without the supplementary cues.

DEGRADED DISPLAYS. It is also sometimes useful to remove information from a display, or to provide less information than state-of-the-art technology is capable of providing. One reason to do this is to save money: if the scene can be degraded or limited without seriously reducing learning, it may be possible to use a less costly image generator. For example, Collyer, Ricard, Anderson, Westra & Perry (1980) found a narrow field-of-view display to be as useful as a wide field-of-view for training circling carrier approaches and landings.

A second reason for presenting a sparse scene rather than a rich one is that rich scenes may simply be too confusing for the novice. In order to teach students to attend to certain critical cues, it is necessary to eliminate extraneous sources of information (Lintern & Roscoe, 1980).

UNCONVENTIONAL DISPLAYS. This category differs fundamentally from the above two, both of which refer to changes made to a scene that essentially depicts what a pilot might see when looking out of his cockpit at the world. The point of view that opens up the possibility of unconventional displays is that it may be important to optimize a display for teaching certain components of the task, rather than for teaching an entire task. Depending on what skills the training device is designed to teach, the optimum display may be totally unlike anything a pilot would encounter when flying an airplane. It could involve unusual perspective viewpoints, extra cues of various kinds, and other techniques such as those discussed by Coblitz (1980).

COMPONENTS OF PERCEPTUAL MOTOR SKILLS

Central to a belief in the potential value of unconventional displays to train certain tasks is a belief in the separability of perceptual and control skill learning. The following paragraphs discuss this concept, presenting several assertions that are little more than opinions at present. No attempt will be made here to defend them on theoretical grounds.

a. Contact flight requires several different kinds of skills. This discussion will be concerned with two of these: perceptual and control skills. Perceptual skills involve whatever a pilot does when he looks out the window and judges his location and orientation relative to external objects. Control skills involve whatever a pilot does with the flight controls to make the airplane do what he wants it to do. Other categories of activities could be included (e.g., decision or response selection), and the categories just described could be further subdivided. However, for the purpose of discussing unconventional displays, it is sufficient simply to make a distinction between perceptual and control activities.

b. Perceptual and control skills can, to some degree, be learned separately. If this occurs, the student must then learn to integrate the skills, that is, to perform them together. Although it will take some time to integrate separately learned components into a continuous, closed-loop task, it may be a small fraction of the time needed to learn the component skills.

c. Perceptual and control skills are probably learned at different rates. The rates depend largely on the type of flying task, and on the experience of the pilot. A skilled pilot learning to fly a new airplane probably does not need many new perceptual skills, except perhaps if the new airplane is flown faster or lower than the old one was. A novice pilot must acquire some new skills that may take a while to learn (e.g., runway shape when on glideslope), and in other cases must simply make adjustments in skills learned previously (e.g., judging closure rates when flying formation).

d. The best display for teaching perceptual skills may not be the best for teaching control skills. A conventional display is probably required to

teach perceptual skills since the objective is to enable the student to interpret the real world as seen from a cockpit. Teaching control skills alone, however, permits more freedom in the choice of displays, since what is required is a means of presenting information that will best enable the student to learn the consequences of his actions. A display that does this most effectively may not look anything like the real world as seen from a cockpit.

e. The effectiveness of a training device may be compromised and its cost increased if it is used to teach both kinds of skills. For example, consider a perceptual skill that requires a great deal of visual realism to learn, but that can be learned quite rapidly in comparison to the control component. If a simulator is designed to teach both skills, its visual system will be very costly in order to provide the realism considered necessary for perceptual training. Even so, it may be inadequate for that purpose, and the pilot may well need to hone his perceptual skills in the aircraft. If the perceptual learning that does occur in the simulator is rapid in comparison with the control skill learning, then during most of the time the simulator is being used, the expensive visual system is simply serving as the medium for control skill learning--a purpose for which it may be overly complex. Alternatives to the above approach might be either to provide a highly detailed open-loop perceptual trainer (e.g., a movie) or to use the aircraft itself for perceptual training and for integrating the component skills.

The discussion above has summarized the main points suggesting that unconventional displays are worth investigating. Such displays may not always, or even usually, be superior to conventional realistic portrayals of the world. We believe, however, that research should be done (a) to explore the possibility that unconventional displays are useful for teaching certain component skills, and (b) to understand the relative lengths of time required for the learning of perceptual and control skill components, as well as the time then required for their integration. Having done this, it will be possible to use simulator and airplane cost data to help determine whether it is cost-effective to use such displays to train control skills apart from perceptual skills.

OBJECTIVE

This experiment was a preliminary investigation of the usefulness of unconventional displays. Its specific purpose was to evaluate the relative effectiveness of four different visual displays for supporting simulator training of two simple flight tasks. A quasi transfer of training (i.e., simulator to simulator) design was used in which subjects trained on one of three displays were then tested on a conventional display, and their performance was compared with that of a control group trained on the conventional display.

SECTION II

METHOD

EQUIPMENT

All training and testing was conducted in the Visual Technology Research Simulator (VTRS) of the Naval Training Equipment Center. The simulator is configured as a twin-jet T-20 aircraft, the Navy primary jet trainer. Flight instruments were occluded in this experiment except where indicated otherwise.

Four displays were chosen to represent fundamentally different ways of presenting information. The technical details of each display will be presented after a brief discussion of the differences among the displays. The four displays were named: the Wide Field-of-View (FOV), the Narrow FOV, the Outside-In and the Flight Instruments displays. Two tasks, Straight-and-level flight and Aileron Rolls, were taught with each of the displays. These two tasks were selected because they differed in certain critical aspects that could have illuminated differential training effectiveness of the various displays. Unfortunately the Aileron Roll data were lost through a programming error, and could not be presented or discussed in this report.

DISPLAYS. The Wide FOV display represented a conventional, out-of-cockpit visual display in that its principal characteristics included a ground plane that obeyed the laws of perspective; an assumed viewpoint of a pilot in the aircraft cockpit; a distinct indication of the desired ground course; size, perspective and motion cues to altitude; and a wide FOV. One presumed advantage of a wide FOV display is that peripheral vision can be used to acquire orientation information which is one of its natural functions (Leibowitz & Dichgans, 1980). There is an implication that a wide FOV display would be superior to a narrow FOV display for performing flight tasks that depend heavily on orientation information. To test this implication, the Narrow FOV display, which presented the same information as the Wide FOV display but over a smaller retinal field, was chosen as one of the four displays. The narrow FOV condition represents a substantially less costly approach to simulation.

The Outside-In display was constructed to be radically different in appearance from the Wide FOV display and to represent simpler and less expensive display technology. It had an outside viewpoint from behind the aircraft; there was no ground plane; altitude and lateral position information were afforded by relative displacement of the aircraft image from a reference mark; and the FOV was small. If the skills learned during training with the Outside-In display were to transfer substantially to the Wide FOV display, it would imply that the method of presenting visual information in simulator flight training need not resemble a natural scene and that visual systems for training certain tasks could be simpler and therefore less costly than many that are presently in use.

The Flight-Instruments display (the T-2C cockpit instruments with no out-of-cockpit display) was chosen because it represented the most extreme departure possible from a conventional visual display; it was a purely a symbolic information display. Acquisition of information did not depend upon spatial perception abilities. The Flight-Instruments display had almost nothing in common perceptually with the Wide FOV display; therefore improvements in performance during the first few transfer trials with the Wide FOV display after training with the Outside-In display would presumably reflect the rate of perceptual learning with the natural representation of the real world.

The four displays are described below and schematically illustrated in Figure 1.

Wide Field-of-View Display. The Wide FOV display portrayed a black-and-white checkerboard ground plane; each checker represented a ground area approximately 300 feet square. A ragged-edged black line, which was about one-third the width of a checker, ran down one column of the checkers and defined a straight course line that the subjects were to follow in Straight-and-Level flight. The top of a band of haze which straddled the area where the checkerboard met the skyline defined the horizon. The Wide FOV display responded according to the laws of perspective to all changes in attitude, heading, position and altitude of the aircraft.

The Wide FOV display was generated by a flying-spot scan of a film transparency. The image was projected onto the spherical screen surrounding the cockpit by the VTRS background projector. The white checkers had a luminance of approximately 2 foot-lamberts (fl). The black checkers and course line had a luminance of approximately 0.5 fl. The contrast of the white to black areas was therefore about 300 percent. The Wide FOV display subtended a visual angle of 160° ($\pm 80^{\circ}$) horizontally by 80° ($+50^{\circ}$ to -30°) vertically.

The Wide FOV was used as the control display for transfer testing. Subjects initially trained with one of the other three displays were subsequently transferred to this display.

Narrow Field-of-View Display. The Narrow FOV display was identical to the Wide FOV display except that a mask on the background projector restricted the FOV to 48° horizontally and 36° vertically. The FOV was centered horizontally about the line of sight. Vertically, the display was positioned with the edges 15° above and 21° below the forward line of sight.

Outside-In Display. The Outside-In display consisted primarily of a solid-surface computer generated image of a TA-4J aircraft seen against a uniform, low-luminance background. The viewpoint of the subject seated in the T-2C cockpit was behind the aircraft image which was able to move laterally, vertically, and in pitch, roll and yaw. The longitudinal distance between the viewpoint and the aircraft was fixed at a constant distance of 1000 ft. The aircraft image responded to the pilot's control inputs in the same manner as a T-2C aircraft. The Outside-In display appeared as an aircraft piloted remotely from a vehicle that maintained a fixed course, altitude and attitude

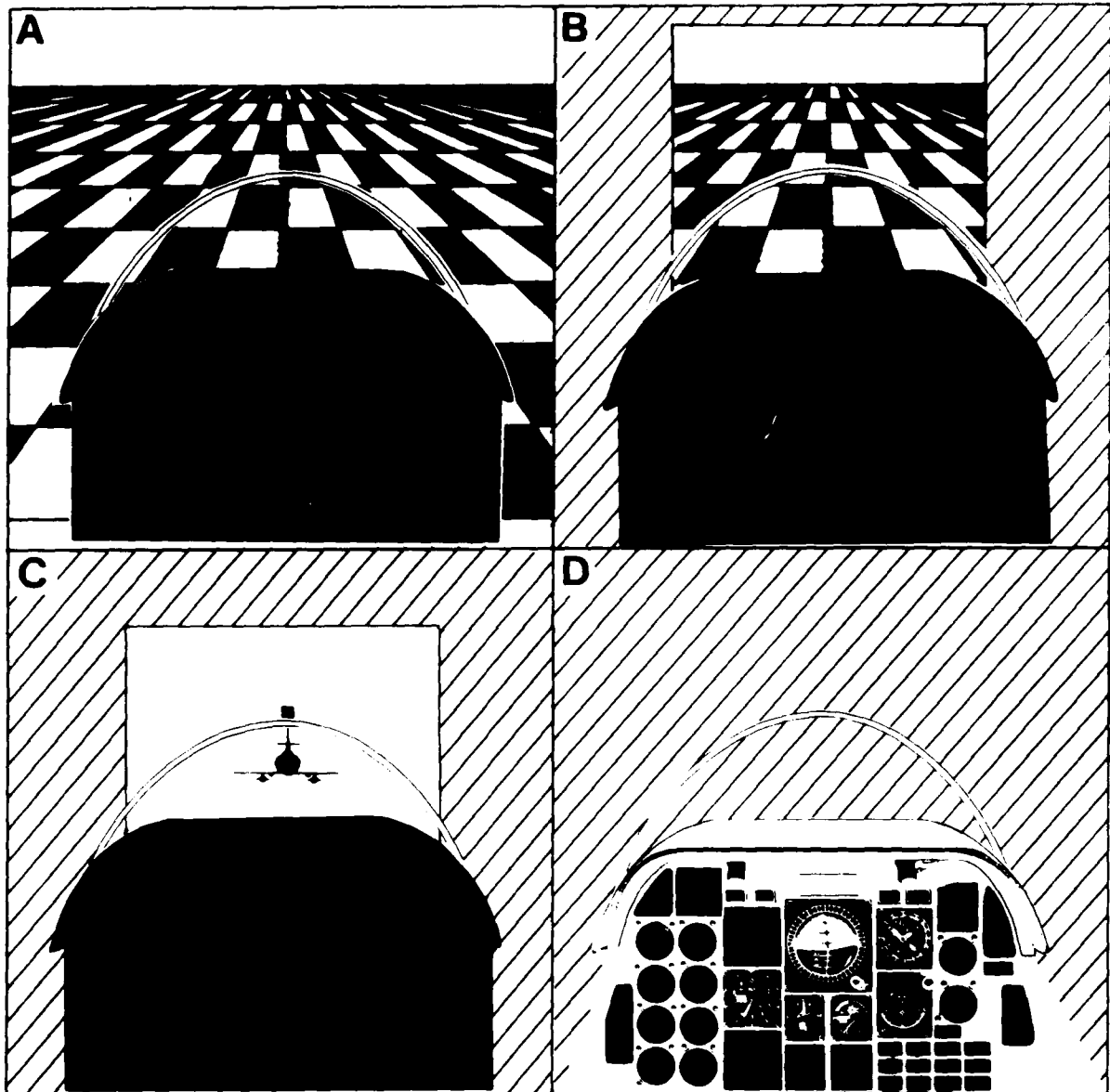


Figure 1. The Four Displays
A. Wide Field of View
B. Narrow Field of View
C. Outside-In
D. Flight-Instruments.

behind the controlled aircraft. Since the aircraft image was seen against a homogeneous background nothing in the visual display provided any impression of forward movement. The desired course and altitude was evident from a reference marker (a square piece of green tape which subtended 1° visual angle on a side) on the screen. The referenced position could be maintained consistently only if the heading of the aircraft image was along the line of sight to the marker. Proper pitch and roll attitude also were required to prevent the aircraft image from drifting in altitude and lateral position, and eventually disappearing from the FOV.

The luminous background was restricted in size to 48° horizontally and 36° vertically by the same mask used in the Narrow FOV display. The aircraft image was produced through the target projector and therefore was not affected by the mask on the background projector. It was, however, limited by a software routine which occluded the aircraft image whenever it moved across any background FOV boundary.

The luminance of the aircraft image was approximately 3 fL. The luminance of the background was about 0.5 fL. The aircraft image was displayed using the high resolution setting (1025 raster lines for the full field) of the target projector. The aircraft image occupied approximately 10 percent of the target projector field in width and 6 percent in height. The actual wingspan of the TA-4J aircraft being about 41 ft., the wingspan of the aircraft image subtended approximately 2.35° .

Flight-Instruments Display. The Flight-Instruments display consisted of only the T-2C cockpit instruments and no out-of-cockpit visual display. A mask placed over the instrument panel exposed only the six instruments necessary to perform the tasks, those being: the attitude (artificial horizon) indicator; the altimeter; the vertical speed indicator; the turn and slip indicator; the bearing, heading and direction indicator (a combination of the gyroscopic compass and relative bearing to TACAN station needle); and the TACAN localizer display.

TASKS. The tasks learned in all cases were: (a) Straight-and-Level flight along a course line while maintaining a desired altitude; and (b) an Aileron Roll with the objective of minimizing changes in lateral position, heading and altitude during and immediately after the roll.

Straight-and-Level. For the Straight-and-Level task, the subject was required to maintain a flight path along the course line, which corresponded to a heading of 360° , and to maintain an altitude of 500 feet. Each Straight-and-Level segment of a trial was 90 seconds in duration, after which time the VTRS control computer would automatically freeze or stop the simulation.

Aileron Roll. For the Aileron Roll task, the subject was required to maintain a constant course line, heading of 360° at an altitude of 500 feet, while executing a 360° Aileron Roll to the right. Each Aileron Roll was started with the aircraft level, on the course line, and at an altitude of 500 feet. Once the trial was begun by the experimenter, the subject was to establish positive control of the aircraft and then execute the roll as soon as

possible. After completion of the roll, the subject was to attempt to correct any errors of heading, altitude, and position that developed during the roll maneuver. The simulation for the Aileron Roll task was set up so that the trial would terminate five seconds after the aircraft had completed 330° of the roll.

Task Characteristics. For both tasks, the throttles were fixed at 84 percent power to produce an aircraft speed of between 250 and 275 knots. The wheels, flaps, and speedbrakes were retracted. The aircraft was trimmed neutral for straight and level flight. Through simulation options, the fuel quantity was fixed and crash override was set. Therefore the weight of the aircraft was constant throughout the trials, and the simulation would not stop in the event of exceeding the force (G) limits of the aircraft or striking the ground. In the event the aircraft was flown into the ground, it would "bounce" up approximately one hundred feet.

Information about aircraft altitude, position and attitude was required to perform both tasks. The sources of course position and altitude information differed among the displays. For the Wide and Narrow FOV displays, the course line was evident from the ragged line running down one column of checkers. Altitude information was available from the apparent size of the checkers, which appeared larger or smaller depending on altitude and varied according to the laws of perspective. For the Outside-In display, desired course and altitude information was available from the marker on the screen. For the Flight-Instruments display, course information was afforded by the Course Direction Indicator (CDI) needle, which pointed to the simulated TACAN station, and the localizer display. Altitude information was afforded by the altimeter. To maintain constant sensitivity of the CDI needle and the localizer needle, the TACAN station was maintained at a constant distance of 1662 ft. forward of the aircraft. This distance was chosen so that full deflection of the localizer needle represented the same lateral position error as the aircraft image in the Outside-In display when at the boundary of the FOV.

Attitude and heading information was also afforded by different sources among the displays. The difference between yaw and heading was discounted in all cases because the aircraft was trimmed to neutral in yaw; there was no crosswind component which would require a crab angle to maintain the desired ground track. Attitude information was provided in the Wide and Narrow FOV displays by the angular relations between the pilot's viewpoint and the combination of the ground plane and the horizon. For the Outside-In display, attitude information was apparent from the pitch, roll, and heading of the aircraft image. For the Flight-Instruments display, pitch and roll information was shown by the attitude indicator and heading information by the compass.

SUBJECTS

Sixteen men, between 20 and 30 years of age, served as paid, volunteer subjects. None of the subjects had previous piloting experience in either aircraft or flight simulators. The subjects were randomly assigned to four

groups of four subjects. Each group was trained with a different visual display.

TRIALS

Each training and transfer trial consisted of three task segments, 90 seconds of Straight-and-Level flight and two Aileron Rolls. The simulation was stopped and reset to the same initial conditions for each segment of a trial. Each subject performed a total of 40 trials; the first 20 were training trials and the second 20 were transfer trials. Training was conducted on one day and transfer tested on the next. The subjects who were initially trained using either the Narrow FOV, Outside-In or Flight-Instruments displays performed their transfer trials using the Wide FOV display. The control subjects used the Wide FOV display for all trials.

PROCEDURES

PRE-TRAINING INSTRUCTION. Prior to the data collection trials, each subject received three phases of instruction consisting of: (a) lecture outside of the cockpit; (b) instruction and familiarization practice in the cockpit; and (c) two practice trials during which the experimenter provided instruction over an intercom from outside the simulator.

Appendix A describes the three phases of instruction given to the subjects.

PRE-TRANSFER INSTRUCTION. A minimum amount of instruction was given to the subjects preceding the transfer trials on the second day. The experimenter advised the subjects trained with the Wide FOV display only that they would perform the same tasks as on the previous day. The experimenter advised subjects trained with the Narrow FOV display the same thing with the additional remark that the same scene would appear but over a larger FOV.

The experimenter gave the subjects trained with the Outside-In and Flight-Instruments displays an explanation of how to use the size of the checkers as a cue to altitude and how to use the height of the horizon on the windscreen to determine pitch attitude for level flight. None of the subjects received any additional instructions nor was any practice permitted prior to the start of data collection on the transfer trials.

CONDUCT OF TRIALS. Both training and transfer trials were conducted in blocks of five with approximately a five minute rest between blocks. The initial conditions for each trial were: altitude - 500 ft.; vertical speed - 0 fpm; airspeed - 254 knots; heading - 360°; position - on the course line; and roll attitude - level.

During the course of the trials, the experimenter or console operator provided no feedback to the subject--with one exception; the subject was informed if his altitude exceeded 1000 ft. because the proper size change of the checkers with altitude occurred only below 900 ft.

The procedures for both training and transfer were the same. After completion of the last twenty trials, the experimenter asked each subject if he had any comments on his performance or had experienced any unusual difficulties. The experimenter also asked if the subject knew of any information omitted from the original instruction which might have aided him in performing the tasks.

DATA ANALYSES

Five performance measures, Altitude Error, Altitude Variability (standard deviation), Lateral Error, Lateral Variability, and Roll Variability were examined. Four-trial means and overall means of log transformed raw scores were calculated for repeated measures analyses of variance (ANOVAs) and for pairwise comparisons with the Newman-Keuls Test (Winer, 1971).

Three sets of analyses were undertaken. The first was of the training data, and the second of the transfer data where the training trials of a control group (Wide FOV training for estimates of transfer from the Narrow FOV, and combined Wide and Narrow FOV for estimates of transfer from the nonperspective displays) were used to establish a reference performance level. Training data of the Wide and Narrow FOV groups were almost indistinguishable and were therefore combined where possible to enhance the power of the statistical tests. A third analysis examined differential transfer by comparing only transfer performance. Statistically reliable display main effects were followed by selected pairwise comparisons. A post hoc procedure for pairwise comparisons was followed because the exploratory nature of this study required comparisons in addition to those specifically related to the experimental hypotheses.

Curves were fitted by eye to plotted data points and have the form of error reduction learning curves. The curve fitting was constrained by the rule that the curves never rise. It was assumed that performance improves with time and any change in error that would require the curves to rise was due to random variation caused by uncontrollable factors of no interest in this exploratory study.

SECTION III

RESULTS

TRAINING

Display main effects were statistically reliable for the five performance measures (Altitude Error, Altitude Variability, Lateral Error, Lateral Variability, and Roll Variability) during training (Appendix B, Tables B1-B5), thereby permitting post hoc comparisons for selected display pairs.

FIELD-OF-VIEW EFFECTS. Only one reliable effect was found for FOV; Roll Variability was slightly less with the Narrow FOV (Table B5). The training scores of the Wide and Narrow FOV are shown in Figures 2 to 6.

EFFECTS OF UNCONVENTIONAL DISPLAYS. The Outside-In group had the lowest Altitude and Lateral Error and Variability scores and the highest Roll Variability scores (Tables B1 to B5). The trends were statistically reliable. Performance for the Flight-Instruments group was reliably poorer than for the combined Wide and Narrow FOV group on both lateral control measures and on Roll Variability. The Altitude Variability of the Flight-Instruments group was reliably lower than for the combined Wide and Narrow FOV group.

TRANSFER

FIELD-OF-VIEW EFFECTS. Display main effects for comparisons of training performance of the Wide FOV with transfer performance of the Narrow FOV groups were statistically reliable (Tables B6 to B10). The Narrow FOV transfer scores were better than the Wide FOV training scores on Altitude Variability, Lateral Error, Lateral Variability and Roll Variability.

EFFECTS OF UNCONVENTIONAL DISPLAYS. Display main effects for comparisons of training scores of the conventional displays and transfer scores of the unconventional displays were statistically reliable for all measures except Roll Variability (Tables B11 - B15). Figures 7-10 indicate that, although transfer performance was sometimes poorer than the conventional training performance at the first four-trial mean, it quickly improved to show an advantage with the late four-trial means. The comparisons of the Outside-In transfer with conventional training were statistically reliable for the Altitude and Lateral performance measures. Flight-Instruments transfer was not reliably different from conventional training on any of the performance measures.

TRANSFER SAVINGS. The numbers of transfer trials required to achieve criterion are shown in Table 1 for all performance measures. The calculations were performed for the three experimental displays. The criterion for the Narrow FOV group was established at the final level of training performance achieved by the Wide FOV group for each performance measure. The criterion for the two unconventional displays was established at the final level of training performance achieved by the combined Wide and Narrow FOV groups.

The only instance in which criterion was not achieved in the transfer phase was for the Outside-In group on the Roll Variability measure. In almost all other instances criterion was achieved in less than half the trials used by the reference group to establish the criterion.

TABLE 1. ESTIMATED TRANSFER TRIALS REQUIRED TO ACHIEVE THE CONTROL PERFORMANCE CRITERION ESTABLISHED IN TRAINING.

Group	Criterion	Altitude Error	Altitude Variability	Lateral Error	Lateral Variability	Roll Variability
Narrow FOV	Wide FOV Training After 20 Trials	12	0	0	1	0
Outside-In	Wide + Narrow FOV Training After 20 Trials	4	5	3	5	*
Flight-Instruments	Wide + Narrow FOV Training After 20 Trials	4	8	6	8	16

*did not achieve the criterion performance in transfer

DIFFERENTIAL TRANSFER

Display main effects for comparisons of transfer performance were statistically reliable for the five performance measures (Tables B16 to B20).

FIELD-OF-VIEW EFFECTS. There was a statistically reliable trend for subjects trained with the Wide FOV to fly with less Altitude Error in transfer than those trained with the Narrow FOV (Table B16). Subjects trained with the Narrow FOV tended to fly with reliably less Altitude Variability in transfer (Table B17). The transfer performance of subjects trained with the Narrow FOV showed reliably less Roll Variability (Table B20). The transfer scores of the Wide and Narrow FOV groups are shown in Figures 2 to 6.

EFFECTS OF UNCONVENTIONAL DISPLAYS. Post hoc comparisons (Tables B16 to B20) showed the Wide FOV transfer performance to be reliably more accurate on Altitude and Lateral Error measures and reliably more stable on measures of Altitude, Lateral and Roll Variability than the Flight-Instruments transfer performance. Transfer performance for the Wide FOV group was more accurate in Altitude control, and less variable in Lateral and Roll control than the Outside-In group. The Narrow FOV transfer performance was less variable in Altitude, Lateral and Roll control than those for either the Flight-Instruments or Outside-In groups. The Outside-In group was reliably

more accurate and less variable than the Flight-Instruments group in Lateral control.

LEARNING EFFECTS. Learning effects are shown in almost all data plots (Figures 2 to 11) and these trends were statistically reliable for all but the Altitude Variability training data (Table B2).

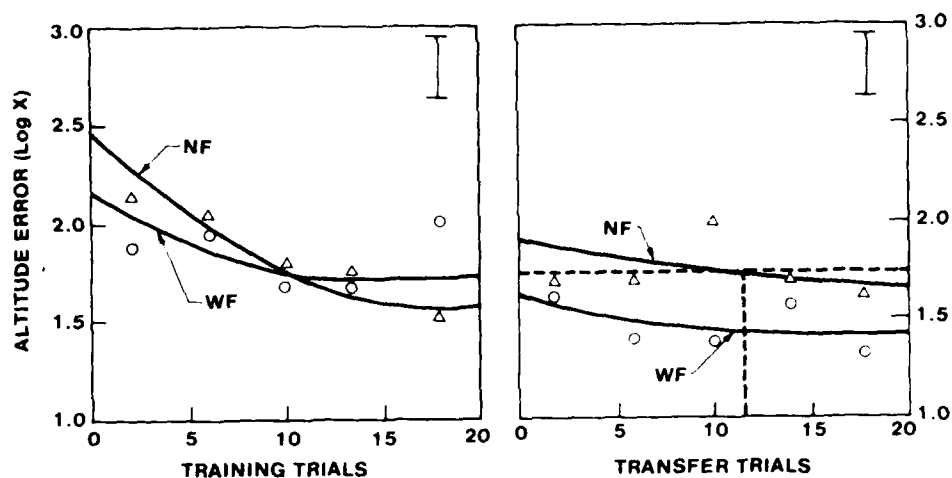


Figure 2. Altitude Error for Wide and Narrow FOV (WF and NF) groups (four-trial means) for training and transfer. (The minimum difference required for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

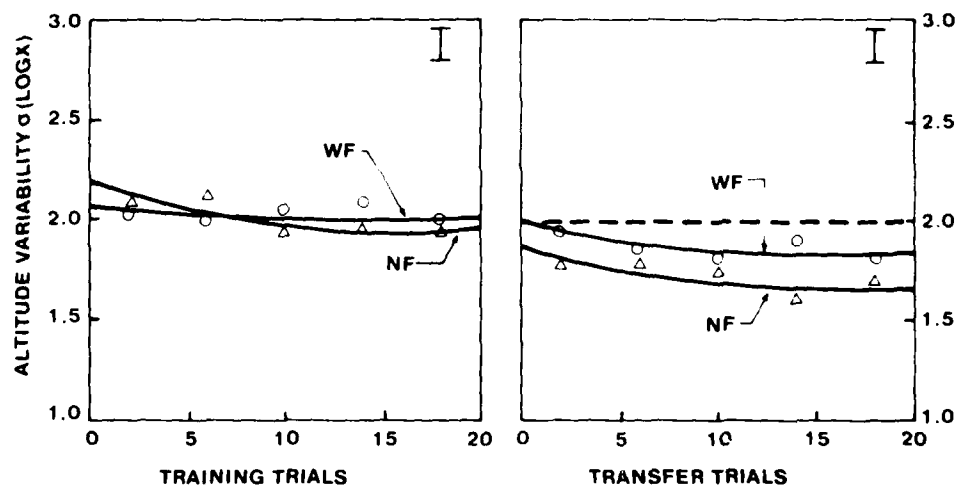


Figure 3. Altitude Variability for Wide and Narrow FOV (WF and NF) groups (four-trial means) for training and transfer. (The minimum difference required for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

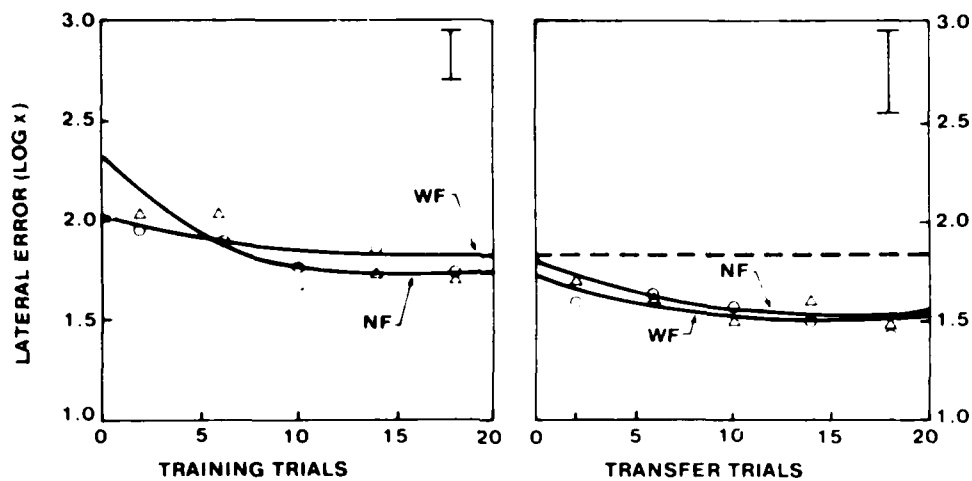


Figure 4. Lateral Error for Wide and Narrow FOV (WF and NF) groups (four-trial means) for training and transfer. (The minimum difference required for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

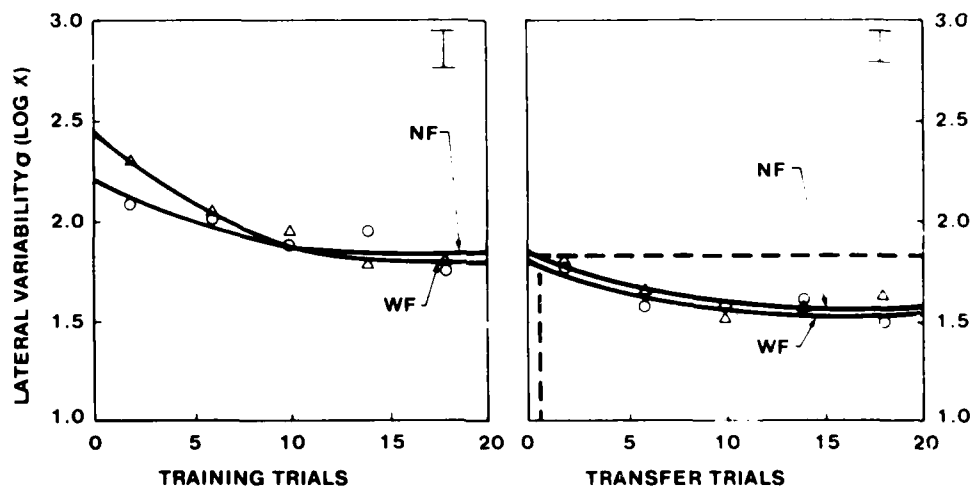


Figure 5. Lateral Variability for Wide and Narrow FOV (WF and NF) groups (four-trial means) for training and transfer. (The minimum difference required for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

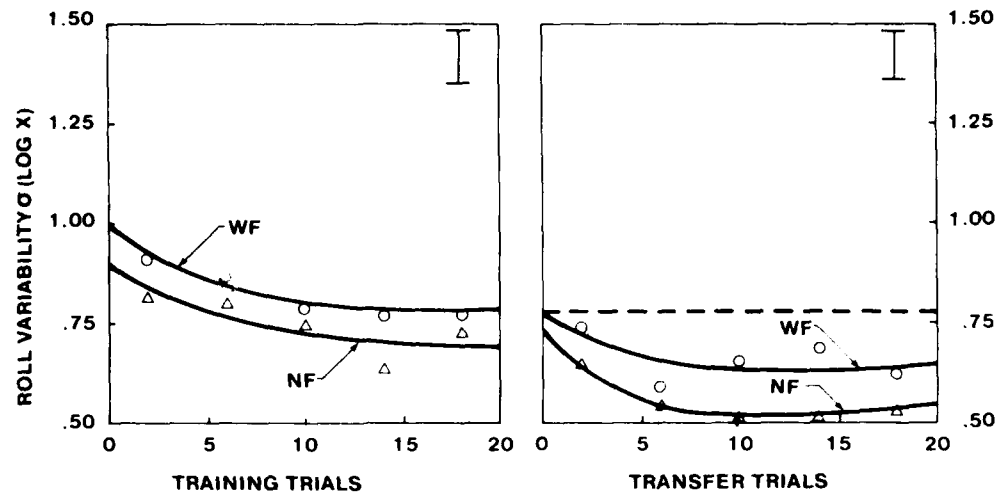


Figure 6. Roll Variability for Wide and Narrow FOV (WF and NF) groups (four-trial means) for training and transfer. (The minimum difference required for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

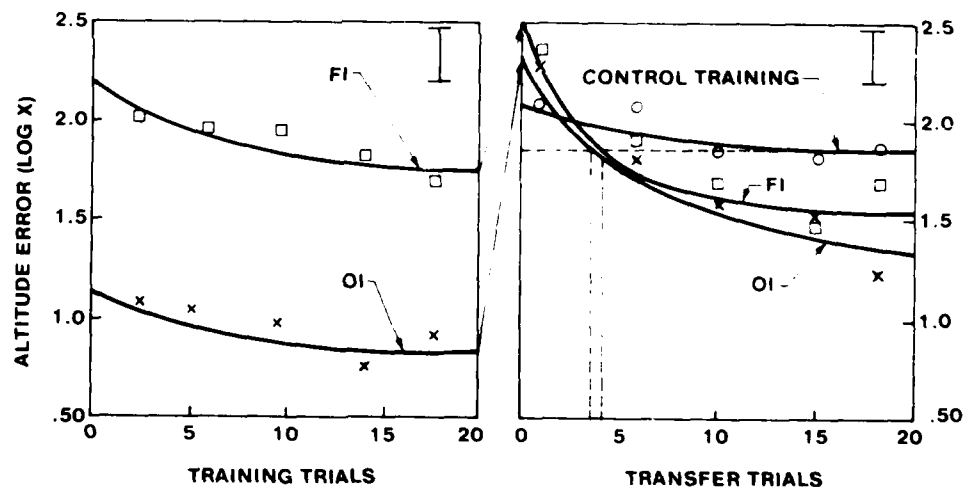


Figure 7. Altitude Error for Outside-In (OI) and Flight-Instruments (FI) groups (four-trial means) for training and transfer. (The control group curve, established as a reference for OI and FI transfer, was fitted to the means of the Wide and Narrow FOV training scores. The minimum difference for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

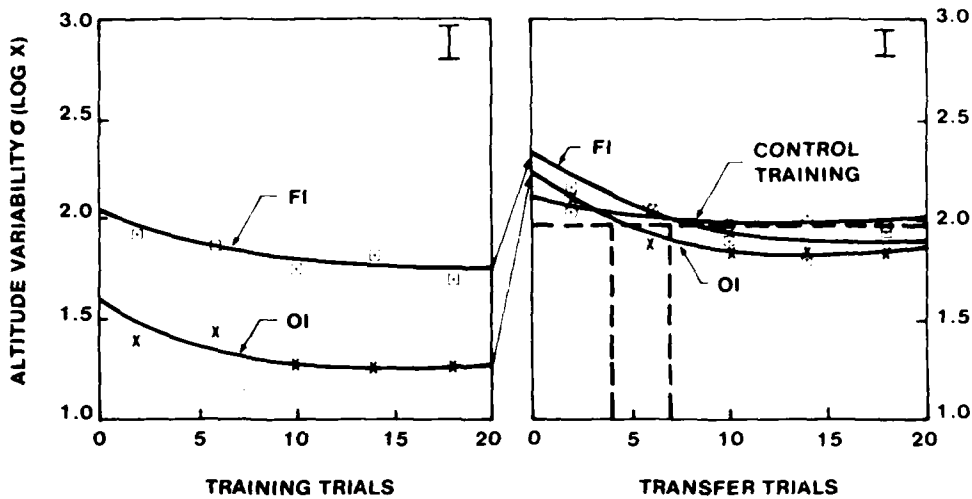


Figure 8. Altitude Variability for Outside-In (OI) and Flight-Instruments (FI) groups (four-trial means) for training and transfer. (The control group curve, established as a reference for OI and FI transfer, was fitted to the means of the Wide and Narrow FOV training scores. The minimum difference for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

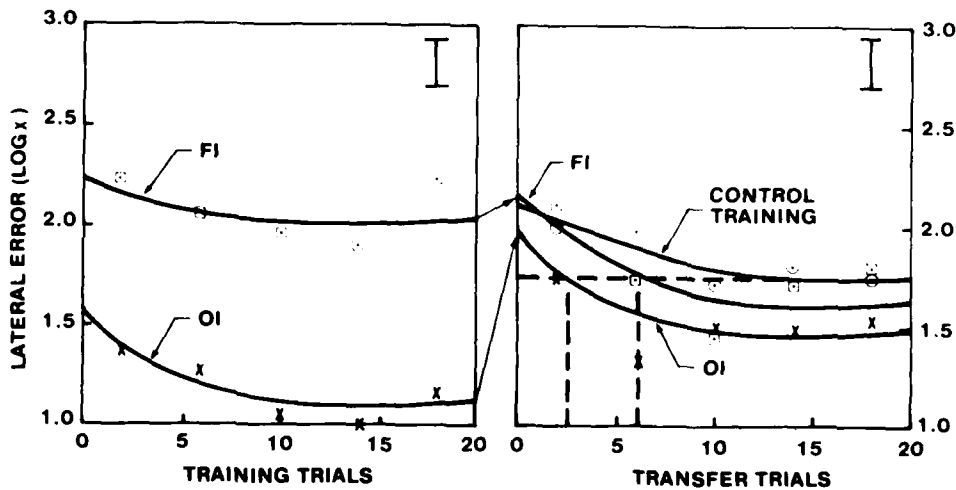


Figure 9. Lateral Error for Outside-In (OI) and Flight-Instruments (FI) groups (four-trial means) for training and transfer. (The control group curve, established as a reference for OI and FI transfer, was fitted to the means of the Wide and Narrow FOV training scores. The minimum difference for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

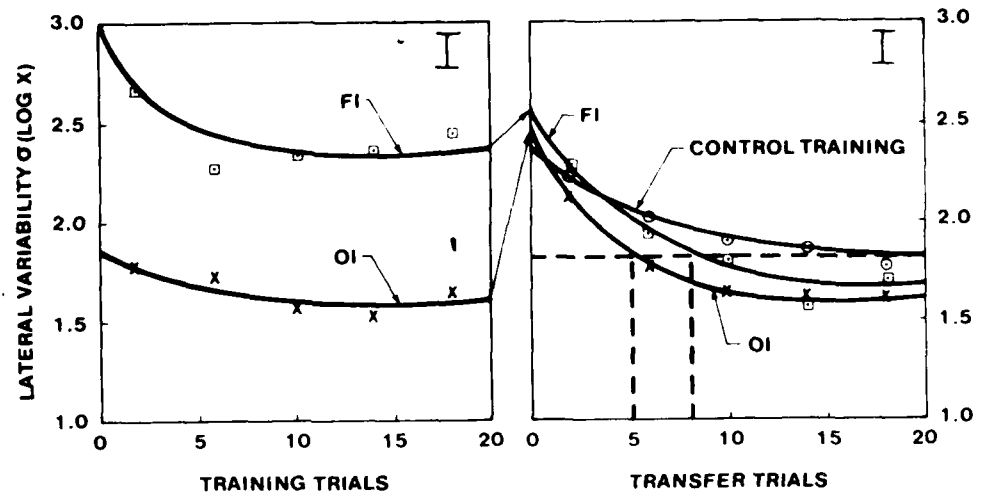


Figure 10. Lateral Variability for Outside-In (OI) and Flight-Instruments (FI) groups (four-trial means) for training and transfer. (The control group curve, established as a reference for OI and FI transfer, was fitted to the means of the Wide and Narrow FOV training scores. The minimum difference for statistical reliability ($F = 3.89$, $p < .05$) is shown in the top right-hand corner (I) of each data plot.)

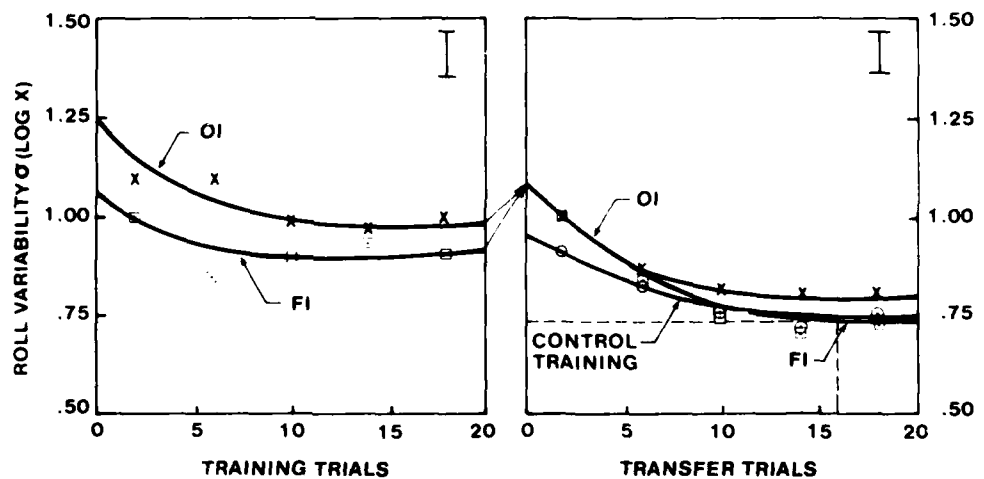


Figure 11. Roll Variability for Outside-In (OI) and Flight-Instruments (FI) groups (four-trial means) for training and transfer. (The control group curve, established as a reference for OI and FI transfer, was fitted to the means of the Wide and Narrow FOV training scores. The minimum difference for statistical reliability ($F = 3.89$, $p < .05$) between groups is shown in the top right-hand corner (I) of each data plot.)

SECTION IV

DISCUSSION

The general conclusion from the results of this study is that visual displays that provide information in ways very different from a conventional pictorial scene are potentially useful means for teaching some contact flying skills. Subjects trained either with the Outside-In or Flight-Instruments displays attained a criterion performance level (established from the control subjects' performance levels after 20 trials) within eight transfer trials, for all measures except Roll Variability. The most encouraging feature of the data is the relatively rapid skill learning as shown by the steep decline in error and variability during initial transfer trials. With this general conclusion as a background, several features of the results, both positive and negative, are worthy of discussion.

TRAINING PERFORMANCE

FIELD-OF-VIEW EFFECTS. The only reliable effect of FOV on training performance was in relation to Roll Variability, which was less for the Narrow than for the Wide FOV display. Westra, Simon, Collyer, & Chambers (1981) have shown higher Roll Variabilities for a narrow FOV in contrast to a wide FOV with simulated carrier landings. Our findings are puzzling, particularly in view of the contrasting results of Westra *et al.* (1981) which were obtained with a task that made a similarly low demand on roll orientation.

Recent conceptualizations of peripheral vision suggest that one of the functions of peripheral vision is to acquire locomotor and orientation information (Leibowitz & Dichgans, 1980; Semple, *et al.*, 1980). Hence, differences in flying performance, and perhaps flight skill acquisition, as a function of FOV, are more likely to occur when the tasks have significant requirements for attitude orientation. As maintenance of course and altitude in the Straight-and-Level task was not considered to depend significantly upon peripheral vision, it was thought unlikely that FOV would make a difference.

As an anecdotal point, during the familiarization practice, two of the four subjects in the Narrow FOV group made several left-right control reversals. It appeared that these two subjects were trying to use the stick to turn the horizon rather than to turn the aircraft. After completion of the transfer trials, they were asked if they thought the Wide FOV was easier to fly than the Narrow FOV. Both said yes; one volunteered that it was easier to be "in" the Wide FOV display. This incident suggests that a wide FOV is helpful for maintaining an inside-out conceptualization in contrast to a tendency to adopt an outside-in conceptualization with the Narrow FOV. Whether this is important in terms of training effectiveness is doubtful because both of the subjects who made the control reversals were soon able to make the control movements in the proper direction. Nevertheless consideration of potential learning problems from control reversal tendencies would be worthwhile in future research.

UNCONVENTIONAL DISPLAYS. The superior altitude and lateral control by the Outside-In group during training probably was a result of the more explicit and precise information provided by that display. For example, the perceptual task of detecting Altitude Error was simpler with the Outside-In display than it was with either the Wide or Narrow FOV displays. With these two displays, subjects could maintain the 500 ft. reference altitude only after they had learned to judge Altitude Error from variations in checker size. Furthermore, subjects had to become sensitive to rate of change of checker size so that the magnitude and timing of their control movements would be appropriate. The precision of the control actions depended upon the precision of the perceptual judgments. While the control requirements for the Straight-and-Level task were the same regardless of the display used, there was a marked difference in the perceptual requirements between the Outside-In and the normal perspective displays.

The training performance of the Flight-Instrument group relative to the conventional groups was reliably better on Altitude Variability and reliably worse on both lateral control measures. As in the Outside-In display, the Flight-Instrument display provided both altitude and lateral error information by displacement of an indicator from a reference mark; in the Flight-Instrument display the indicators are needles and the reference marks are symbols on the flight instruments. Unlike the Outside-In display, the Flight Instrument information sources are not integrated, and symbolic interpretation is required. The accuracy of error information provided by the Flight-Instrument display probably accounts for the reliably superior performance of that group relative to the normal perspective groups on Altitude Variability. The required distribution of attention among the instruments and the need to mentally translate indicated angular displacements of the two instruments that provided lateral position information into lateral position displacement probably accounts for the poorer performance on the lateral control measures. It was somewhat surprising that the Flight-Instruments group performed as well as it did, considering that the subjects had no prior flight experience and received only a twenty minute briefing on the functions of the flight instruments.

The difference in Roll Variability among the groups during training was an interesting result (higher values indicate greater numbers of banks or larger roll angles). Since banking is necessary to turn the aircraft to correct lateral position errors and to change heading, Roll Variability could be expected to correlate with lateral position error. The Outside-In group demonstrated the best lateral control performance but showed the greatest variability in roll. The Flight-Instrument group demonstrated the worst lateral control performance but still had the second highest variability in roll. The Outside-In and Flight-Instrument groups differed reliably from each other and also from the normal perspective groups.

Roll Variability seemed to be more a measure of control style that developed as a consequence of the nature of the display used during training than of lateral control. Visually, changes of bank were dramatic in the normal perspective displays because the whole visual scene rotated. In the Outside-In and Flight-Instruments displays, changes in bank angle were

reflected by the roll of the relatively small aircraft image or the artificial horizon bar. The visual impact of the roll information source may have affected the degree of change of bank the pilot was willing to produce. A particular roll angle may have appeared large in the Wide or Narrow FOV displays but small in the Outside-In or Flight-Instrument displays. It is not clear what significance the effect of display type on Roll Variability might have. The magnitude of this measure evidently cannot be interpreted as better or worse performance per se when the flight task is something other than maintaining a level attitude.

TRANSFER

One useful question to be asked of a transfer-of-training study is whether experience with a trainer that only partially represents the criterion system can teach students anything worthwhile about the criterion task. The costs of procuring such a system and of extending the training curriculum to include time on it, might be justified on the basis of expected savings in time on the criterion system. While the time saved on the criterion system will usually be less than that spent on the trainer, a substantial cost differential in favor of the trainer might allow that extra training to be cost effective. The critical comparisons are those between training trials of a control group and the transfer trials of those groups that had been trained with the experimental conditions.

FIELD-OF-VIEW EFFECTS. The data indicate that subjects transferring from the Narrow FOV quickly attained the performance achieved by the Wide FOV group in their last four training trials. On most dimensions of performance, the Narrow FOV group's first four transfer trials were as good as the training criterion established by the Wide FOV group. Only with Altitude Error was there any noticeable delay in achieving the criterion performance level, and even in that case it was achieved in a moderately short transfer period. This result is not surprising in view of the earlier comments on the role of peripheral vision in locomotor control and the nature of the Straight-and-Level task.

UNCONVENTIONAL DISPLAYS. Although the transition from unconventional to conventional displays appeared to produce early negative transfer, this effect if real, was small and was soon overcome in that transfer performance of the groups trained with the non-perspective displays quickly surpassed the training performance of the perspective display groups. Using the mean of the final training performance of the two conventional display groups as a criterion, groups trained with the unconventional displays could achieve that criterion during transfer (on all but the roll measure), in less than half the trials allocated to train the conventional display groups.

Clearly something was learned with the Outside-In and Flight-Instrument displays that facilitated the rate of learning with the perspective displays. Since the aircraft dynamics and task requirements were the same in all cases, it seems reasonable to conclude that the control elements of flying skills, as defined at the beginning of this report, were learned regardless of the display used. Due to the design of this experiment it is not possible to determine the amount of control skill learning that occurred during training

as a function of the different displays, nor the degree of control skill learning by the Outside-In and Flight-Instrument groups that occurred during transfer. However the findings are consistent with the hypothesis that control skills can be learned with very different kinds of information displays and that the rapid increase in performance during transfer is due primarily to rapid perceptual learning. If control learning is a slower process than perceptual learning, it would be expected that once control skill is learned, learning to use a different information display to perform the same task will be relatively rapid.

The initial and brief decrement in performance when transferring from unconventional to conventional perspective displays was not statistically reliable and was poorly defined. In a simulator-to-simulator training paradigm it may be theoretically significant if it could be established as a genuine effect but, due to its transitory nature, it would have no practical significance. However, if such an effect were found in a simulator-to-airplane transfer paradigm, it could be operationally critical in that any substantial decrement in performance, no matter how transitory, can be disastrous if it occurs in actual flight. Although adequate care at the transition from simulator to aircraft would almost certainly alleviate this potential danger, it remains an important issue that could easily be examined in most transfer studies.

DIFFERENTIAL TRANSFER

Training programs could benefit not only from inexpensive devices that teach important components of the task, but also from devices not necessarily less costly than the criterion system, that allow essential skills to be learned more quickly. While the notion that transfer between two devices increases monotonically with their similarity is a well established principle of perceptual-motor transfer (Holding, 1976) some data indicate that it is not universal. Gordon (1959) & Lintern (1980) have shown that experience with special training tasks can teach more about a criterion task than can equivalent experience with the training task itself. Comparisons of the transfer performances of the four groups were used to investigate this issue.

FIELD-OF-VIEW EFFECTS. There was slight evidence that training with the Narrow FOV was more efficient than with the Wide FOV. Note that this tendency was observed only with Altitude Variability, was not well supported with tests of statistical reliability, and was contrary to trends observed for Altitude Error. Thus it might, under some circumstances, be dismissed without comment. Furthermore, the training performance for the two displays was similar, and while a disadvantage for the Narrow FOV group upon transfer to the Wide FOV might seem reasonable, it seems unlikely that an advantage could be shown after transfer from the Narrow FOV unless there had been some advantage shown in training. Nevertheless, FOV is an important issue with substantial cost implications for aviation. Any credible evidence that a narrow FOV could provide superior training on some tasks would be noteworthy. This is important enough to encourage further investigation, even in view of the insubstantial nature of the evidence provided here.

UNCONVENTIONAL DISPLAYS. There were several indications from the transfer data that neither the Outside-In display nor the Flight-Instruments display provided as effective training for transfer to the Wide FOV as did the Wide FOV.

COMMENTS ON THE STUDY

Several features of the study limited the amount of information that could be gained and to some extent, limited the generalizability of the conclusions. The most important of these will be discussed with the aim of indicating their impact on the significance of the data.

STATISTICAL POWER. The between-subject variability appeared high and that coupled with the small sample size limited the power of the statistical tests (power is defined as the capability of the test to demonstrate statistical reliability where a real difference of specific magnitude exists). Some increase in power is essential for future transfer-of-training studies, and could be gained with a larger number of experimental subjects, with improvements in across-trial reliability and with covariates that account for a useful portion of the between subject variance. The selection of an appropriate covariate may be difficult, but given that many of the flight tasks that could be used in future display research are compensatory in nature, the demonstrated convergence of "Air Combat Maneuvering" (an ATARI video game) on compensatory tracking (Kennedy, Bittner, & Jones, 1980) suggests that it could be an appropriate covariate. A preliminary investigation of appropriate covariates is planned for the future VTRS research.

DIFFERENCES AMONG THE DISPLAY TYPES. The FOV difference between two of the displays was a simple and specific difference. However, the Outside-In and Flight-Instruments displays differed from the normal perspective displays in many ways. The Outside-In and Flight-Instruments displays were chosen to be representative of fundamentally different ways of displaying information relative to the conventional, real or simulated view from the cockpit. Because only a single case of both an Outside-In and a Flight-Instruments display was used, it is impossible to say what particular characteristics of these displays influenced training and transfer performance. With the exception of FOV, it is not possible to generalize the conclusions about the value of these displays to other display formats or variations.

DISPLAY GAIN AND COUPLING. An important consideration for interpreting the results of this study is the way deviations from the desired flight profile were reflected in the displays, i.e. the coupling of performance error to display error. For the normal-perspective display, the nature of the coupling is almost completely determined by the laws of perspective and the speed and altitude of the aircraft, although the size of the checkers and width of the course line represent features of the real world that can be considered to have some effect on the pilot's sensitivity to error information in the display (i.e. his perceptual gain). However, for both the Outside-In and Flight-Instruments displays, the coupling and gain of the information could not be made equivalent to that of the normal perspective display in any definite way.

One example should clarify the nature of the coupling and gain problem. For the Outside-In display, lateral course error was indicated by the deviation of the aircraft image from the marker placed at the center of the screen. For the Flight-Instruments display, lateral error was indicated by the deviation of the Course Direction Indicator (CDI) needle. For the Outside-In display, the relation of the magnitude of course error in feet to angular deviation of the aircraft image depended on the simulated viewing distance between the observer and the aircraft. Depending on whether the viewing distance was large or small, a constant angular deviation of the aircraft image represented a small or large difference in lateral error. Observation distance for the Outside-In display determined the gain for the lateral error display. Similarly, for the Flight-Instruments display the simulated distance between the aircraft and the TACAN station determined the gain of the CDI needle. It is not apparent what distance between the aircraft and the TACAN station was equivalent in gain to that of the normal-perspective display. Similar but more complex issues could be raised about the equivalence of gain for heading and altitude information among the four displays used in this study.

Changes in gain of the display elements may have important effects on both training and transfer performance. Thus, the gain used in the present experiment may or may not have been near optimum. In either case, since only one gain was used for each display type, the effect on the transfer results is uncertain.

TASK DIFFERENCES. One of the purposes of this study was to determine whether FOV for the conventional display would differentially affect performance depending on the nature of the task. This expected difference in performance was based on the hypothesis that peripheral cues are more important for tasks characterized by large, rapid changes in aircraft attitude and altitude. Due to the loss of the Aileron Roll data, the differential effects of FOV on learning or performance for the two tasks could not be determined.

FUTURE RESEARCH RECOMMENDATIONS

This study has demonstrated that unconventional visual displays can be used effectively for training some contact flying skills. The rapid increases in performance by the Outside-In and Flight-Instruments groups during transfer are consistent with a belief that perceptual learning and control skill learning can occur independently. It is suggested that for some tasks, control skills can be learned using a visual information display very different from the criterion display, and that perceptual learning can be relatively rapid once the criterion display is used. Due to the design of this study it is not possible to conclude that the rate of learning during transfer reflects only perceptual learning or that perceptual and control skill learning are completely separable components. However, the findings of this study are encouraging and indicate that, because of the implications for cost and effectiveness of training, these are issues worthy of additional research.

Future research should be directed toward a clearer resolution of the roles of perceptual and control skill learning in the acquisition of complex

flying skills. This is an issue of significant theoretical importance. At the same time, the practical value and potential cost benefits of teaching flying skills using unconventional displays should be investigated. It may be possible to pursue both objectives in the same experiments. However, for the sake of clarity, the recommended research on these two issues will be described separately.

PERCEPTUAL LEARNING VS. CONTROL SKILL LEARNING. The relative contributions of perceptual learning and control skill learning in the acquisition of flying skills could be investigated with a transfer-of-training experiment using two different displays and two different control systems. After pretraining on a selected control-display system experimental groups could be transferred either to a different display or to a different control system while control groups could be transferred either to the same control-display system or to a system in which both were different. Appropriate transfer comparisons could indicate the relative amounts of perceptual and motor learning that had been accomplished in the pretraining phase.

Based on our transfer data which showed that subjects could adapt quickly to a new display, it would be expected that control skills would show stronger transfer between different displays than would perceptual skills between different control system. Nevertheless the conclusions of this study are limited because they are based only on results with a Straight-and-Level task. It is difficult to ascertain in advance whether perceptual or motor skills will be more difficult to learn with any specific task. If the proposed experiment could be undertaken with a sufficient range of tasks, it may be possible to formulate principles of relative perceptual and motor learning difficulties for classes of tasks, and thereby to specify less expensive devices for preflight training.

UNCONVENTIONAL DISPLAYS FOR TEACHING COMPLEX FLYING SKILLS. The relatively high positive transfer of training from the Outside-In and Flight-Instruments displays to the normal perspective display condition suggests that it would be profitable to determine the value of using unconventional displays for training other, more complex flying skills. Flight Instruments may be more limited in potential training applications than the Outside-In display or some extension of it. Therefore, this discussion will concern research on the potential applications of an Outside-In type display. However, it should be borne in mind that it may be possible to use Flight Instruments for the same purpose.

The Straight-and-Level task used in this experiment was relatively simple. Research with more complex flight tasks would determine whether this type of display has broad potential advantages for training. These advantages may include training effectiveness as well as training-cost effectiveness relative to a conventional display. Three tasks considered to be good candidates for exploratory research with an Outside-In display are aerobatic maneuvers, helicopter landings on decks of small ships, and air-to-ground attack. Aerobatic maneuvers, which are taught as a prelude to air combat maneuvering training, could be taught with little or no modification to the Outside-In display used in the present study. The potential virtue of using this display for aerobatics is that the pilot could see the course of the

aircraft through space throughout the maneuver. Flight training manuals illustrate various aerobatic maneuvers by depicting the ideal path for an aircraft to follow. Implicit in illustrations of this kind is the assumption that an overview of the path of the maneuver promotes understanding of the task requirements and, more importantly, that the pilot develops a mental map of the flight path of the aircraft which he then uses to guide his control behavior in the aircraft. If the pilot indeed does use a mental map, the Outside-In display would show the actual path flown by the aircraft and presumably would provide explicit, continuous feedback to the pilot about his control of the maneuver.

Another candidate task for training research with an Outside-In display is landing a helicopter on the deck of a small ship. Simulators currently used for this purpose require a wide FOV with a large lookdown angle to the side because once the helicopter is over the deck, very little of the ship can be seen through the forward windows. An Outside-In display could provide a birds-eye view, that would permit the pilot to see the images of the helicopter and the ship simultaneously. This kind of display might promote more rapid learning of the task than a conventional display with an out-of-cockpit view.

A third interesting candidate task is low level flying--either high speed terrain following in a fixed-wing aircraft or nap-of-the-earth flight in a helicopter. One display approach would be to provide a side viewpoint that moves with the aircraft. Thus the pilot could watch himself as he attempted to skim over the rolling terrain that scrolls past. His altitude and range to various obstructions along the flight path should be relatively easy to judge with such a display. This task is especially appealing as it has proven to be among the most difficult for a conventional CIG display to support (Richards & Dismukes, 1981). The reason for this is the need to provide texture in sufficient quantity for the pilot to judge distances to nearby terrain. If a low-cost unconventional display could be shown to provide significant amounts of control skill training for this task, it would be a major research accomplishment.

SECTION V

CONCLUSIONS

This study was a preliminary investigation to determine whether unconventional visual displays could be used for teaching certain components of flight skills. In general the results of this experiment were encouraging. Flight-naive subjects learned to perform a fundamental flight task reasonably well within 20 trials using either the Outside-In or the Flight-Instruments display. There appeared to be good transfer to a conventional display with no obvious peculiarities in the data that might suggest strong interference from learning with the experimental displays. FOV did not importantly affect training or transfer performance of the Straight-and-Level task. In particular, there was no evident advantage of using a Wide FOV for training of the Straight-and-Level task.

The belief that control skills could be learned using any display that provides the necessary information was supported by the results. The results also suggest that perceptual learning may occur quickly relative to control skill learning. Unconventional visual displays show promise as cost effective means for teaching some flight skills, as it appears that relatively inexpensive visual displays could be used to support control skill learning. Even if expensive, high fidelity displays are found to be useful for teaching perceptual skills that will be used in the aircraft, it may be economical to pretrain with simpler and less expensive displays. Thus research on optimizing visual displays for flight training need not be restricted to conventional out-of-cockpit scenes. Furthermore it is possible that unconventional displays would prove to be superior to conventional displays on a time-to-train as well as a cost basis.

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APPENDIX A

INSTRUCTIONS TO SUBJECTS

Each subject received a copy of an "informed consent" form that described the purpose of the experiment and his duties and rights as a subject. Basically, his rights were that he was entitled to have any question about the experiment answered to his satisfaction. The form also included assurance that his name would be kept confidential and not reported with his data in publications or presentations of the results of the experiment. Each subject signed a copy of the form to acknowledge that he understood his rights and his role as a subject.

There were three phases of instruction: (a) a lecture on control of the T-2C aircraft outside the aircraft; (b) instruction and familiarization in the cockpit; and (c) two practice trials.

LECTURE INSTRUCTION

The lecture phase of instruction explained the control characteristics of the T-2C aircraft. About twenty minutes was devoted to explaining the flight characteristics of the aircraft, how stick movements affect the attitude and flight of the aircraft, proper procedures for performing the Straight-and-Level and Aileron Roll tasks, and control technique.

In an explanation of the flight characteristics of the aircraft, the experimenter told each subject that the aircraft was stable and that whatever the attitude of the aircraft, it would tend to continue to fly in that attitude until some control action was taken. The experimenter also pointed out that the aircraft had a certain amount of inertia; therefore the altitude or heading change developed slowly whenever the pitch attitude or roll attitude of the aircraft was modified to change altitude or to turn. The experimenter emphasized that once an attitude change was produced by movement of the stick, the subject should not try to hurry the altitude change or turn rate by further control actions; rather, he should wait until he was certain of the effects of the attitude changes just produced.

The stick was the only control the subject was required to use. Therefore the experimenter pointed out the effects of stick movements on pitch, roll, and subsequently, on changes in altitude and heading. In spite of the fact that the pedal need not be used to make a coordinated turn in the T-2C aircraft, the function of the pedals was explained. The experimenter told each subject that he would not find it necessary to use the pedals to control the aircraft.

The method for correcting course track errors was explained as follows: first, the subject should turn to establish a heading which would intercept the course line, preferably at an angle of 10° or less; second, he should turn to the heading of the course line before it had been intercepted. The

experimenter underscored the need to anticipate when turning onto the course in order to avoid overshooting.

Each subject was informed that when he made turns he should do so with a relatively shallow roll angle -- not to exceed approximately 30° . The experimenter also explained the tendency of the nose of the aircraft to drop when making a turn. The experimenter noted that the application of a small amount of back pressure on the stick during the turn would keep the nose of the aircraft from dropping and prevent loss of altitude.

Pushing forward on the stick, the experimenter explained, would cause the nose of the aircraft to drop while pulling back would cause the nose to rise. Furthermore, once the change in pitch angle had been effected, the subject was told that the stick should be centered; the aircraft would then follow the established pitch angle and either lose or gain altitude.

The proper performance of the Straight-and-Level and Aileron Roll tasks were covered next in the lecture instruction. The requirements for the Straight-and-Level task were simple and straightforward: attempt to fly the course line and maintain altitude and a level attitude using the control procedures previously described. The explanation of the procedure for performing the Aileron Roll task was brief during the lecture because understanding of instruction for this task would be easier with the subject in the cockpit.

The procedure for executing the Aileron Roll task was based on a description provided by a Navy pilot. The procedure, as explained to the subject, was to establish a level pitch and roll attitude; pull back hard on the stick for about one second to establish a nose-up attitude of approximately 8° to 10° ; immediately center the stick; move the stick as quickly as possible as far as it would go to the right; and hold it there until it was time to stop the roll. The aircraft then would rotate wing over wing through a full 360° roll. The subject was told that just before the roll was completed, he should move the stick smartly to the left to arrest the roll as the wings came level. The experimenter emphasized that too little or too great a pitch movement when the maneuver was begun would result in excessive gain or loss of altitude. In other words, the subject was told that there was an optimum pitch up that would minimize excursions in altitude. The experimenter also informed subjects that it was important not to make inadvertant pitch movements during the course of the roll. He revealed that once the aircraft had completed the roll the subject could attend to his attitude, heading, altitude, and position with respect to the desired course. Completion of the roll was also the time to correct any error in these variables that had developed as a consequence of performing the roll.

Each subject was told that the proper method for controlling the aircraft during the performance of his tasks was to make corrections in the following order: roll, pitch, heading, altitude, and lateral position. The experimenter stressed the fact that the subject should run through this order mentally and correct each variable sequentially. Eventually, the experimenter emphasized, the subject would be able to correct more than one variable at a

time; however, taking things in sequence was affirmed as a good procedure which should definitely be followed when the subject first started flying the simulator.

Every subject received the lecture instruction outlined above. The experimenter answered any questions raised by the subjects. The subjects who were trained with the Flight-Instruments display received approximately an additional 20 minutes of instruction on the function of the instruments. A series of 35mm slides depicting the cockpit instruments with different readings was used to illustrate the functioning of the instruments.

COCKPIT INSTRUCTION

Once in the cockpit, each subject was given the opportunity to become familiar with the feel of the stick and the appearance of the display. The objective of the instruction received during this phase was to insure that the subject understood the procedures for performing the task and acquired some rudimentary ability to control the aircraft. This phase of instruction was not possible to structure formally. Rather, the instruction was highly dependent upon the individual's needs. In general however, the instruction proceeded by allowing each subject to fly for approximately three or four minutes and to exercise roll and pitch control of the aircraft. Once the subject gained some appreciation of the effects and sensitivities of the controls the experimenter asked him to try to hold a level attitude. The subject was then given a few more minutes practice and instruction in flying straight and level. Next he was instructed on control of heading. The experimenter then explained an altitude control and allowed the subject to practice it. Lastly, position control, i.e. trying to fly the desired course, was attempted.

When, in the judgment of the experimenter, the subject understood proper control techniques and exhibited some ability to control the aircraft while flying straight and level, he was instructed on the procedure for the Aileron Roll. The experimenter demonstrated one roll while the subject was still seated in the cockpit. During the demonstration the experimenter talked through the sequence of control actions for the maneuver; he also had the subject hold his hand lightly on the stick to gain some appreciation for the timing and movement of the stick during the various phases of the maneuver. After the demonstration each subject was permitted to try three rolls with feedback being provided by the experimenter. Practice of the three rolls ended the in-cockpit phase of instruction. For each subject, the amount of in-cockpit practice and instruction required between 20 and 30 minutes.

As might be expected, cockpit instruction depended a great deal on the type of display the subject was using. Subjects who trained with the Wide or Narrow FOV display were instructed to pay attention to the size of the checkers as a cue to altitude. The subject was told that the time to note the size of the checkers was at the beginning of each trial; the experimenter suggested that the separation of the windscreen struts could serve as a size comparison. He also advised the subjects to note the height of the horizon on the windscreen to aid level flight.

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For subjects trained with the Outside-In display, the experimenter pointed out that the marker on the screen indicated where the aircraft should be for proper altitude and course control. The subjects were also informed that the aircraft image would disappear if it crossed the boundary of the background FOV.

Special instructions to the subjects trained with the Flight-Instruments display consisted primarily of emphasizing control of roll, pitch, heading, altitude, and position in the recommended sequence of priority. The experimenter explained that when off course, but on heading which would bring them back to the course, the subject should notice when the Course Direction Indicator started to approach the desired indication, i.e., the centered position. When this occurred, the subject should begin to turn onto the proper heading to maintain the course, i.e. 0°.

PRACTICE TRIALS

Prior to the beginning of data collection, each subject was given two complete trials of practice on the Straight-and-Level and Aileron Roll tasks with feedback provided by the experimenter over an intercom. The control console of the VTRS had a graphic representation of the relevant aircraft instruments and a CRT repeater display of the visual scene as it appeared to the subject in the cockpit. These two displays enabled the experimenter to assess the subject's performance and provide feedback during the practice trials. Most of the feedback for all subjects concerned the altitude for the Straight-and-Level task and amount of pitch up at the beginning of the Aileron Roll task. Other kinds of feedback, including words of encouragement, were occasionally provided.

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APPENDIX B

DATA SUMMARY TABLES

TABLE B1. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR ALTITUDE ERROR (LOG x): TRAINING DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	14.905	3	69.11	**
Trial Blocks (T)	1.098	4	5.09	**
D x T	.3108	12	1.44	-
Error	.2157	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	1.89	1.92	1.75	1.79	2.09	1.888
Narrow FOV (NF)	2.16	2.07	1.90	1.85	1.62	1.920
Outside-In (OI)	1.28	1.20	1.03	.71	.95	1.034
Flight Inst (FI)	2.05	1.97	1.89	1.79	1.72	1.884

POST HOC COMPARISONS

WF vs NF	-
OI vs FI	**
OI vs WF + NF	**
FI vs WF + NF	-

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TABLE B2. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (**: $p < .01$) OF POST HOC
COMPARISONS FOR ALTITUDE VARIABILITY (σ (LOG x)):
TRAINING DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	8.1901	3	96.26	**
Trial Blocks (T)	.1971	4	2.32	-
D x T	.0463	12	.54	-
Error	.0851	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	2.03	2.02	2.04	2.09	2.00	2.036
Narrow FOV (NF)	2.05	2.11	1.94	1.95	1.95	2.000
Outside-In (OI)	1.41	1.45	1.27	1.26	1.29	1.336
Flight Inst (FI)	1.92	1.86	1.76	1.83	1.70	1.814

POST HOC COMPARISONS

WF vs NF	-
OI vs FI	**
OI vs WF + NF	**
FI vs WF + NF	**

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TABLE B3. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR LATERAL ERROR (LOG x): TRAINING DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	12.0393	3	46.09	**
Trial Blocks (T)	.9400	4	3.60	**
D x T	.1439	12	.55	-
Error	.2612	294		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Wide FOV (WF)	1.96	1.89	1.75	1.86	1.76	1.844
Narrow FOV (NF)	2.03	2.04	1.67	1.74	1.74	1.844
Outside-In (OI)	1.38	1.27	1.06	1.01	1.18	1.180
Flight Inst (FI)	2.23	2.05	1.96	1.90	2.28	2.086

POST HOC COMPARISONS

WF vs NF	-
OI vs FI	**
OI vs WF + NF	**
FI vs WF + NF	**

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TABLE B4. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (**: $p < .01$) OF POST HOC
COMPARISONS FOR LATERAL VARIABILITY
(σ (LOG x)): TRAINING DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	7.8727	3	61.94	**
Trial Blocks (T)	1.1040	4	8.69	**
D x T	.1453	12	1.14	-
Error	.1271	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	2.12	2.01	1.89	1.96	1.76	1.948
Narrow FOV (NF)	2.30	2.02	1.92	1.78	1.80	1.964
Outside-In (OI)	1.79	1.71	1.57	1.53	1.64	1.648
Flight Inst (FI)	2.67	2.27	2.33	2.35	2.45	2.414

POST HOC COMPARISONS

WF vs NF	-
OI vs FI	**
OI vs WF + NF	**
FI vs WF + NF	**

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TABLE B5. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (*: $p < .05$, **: $p < .01$)
OF POST HOC COMPARISONS FOR ROLL VARIABILITY
(σ (LOG x)): TRAINING DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.1261	3	19.85	**
Trial Blocks (T)	.1626	4	2.87	*
D x T	.0296	12	.52	-
Error	.0567	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	.92	.87	.79	.79	.78	.830
Narrow FOV (NF)	.83	.80	.75	.64	.73	.750
Outside-In (OI)	1.10	1.09	.98	.96	1.00	1.026
Flight Inst (FI)	1.00	.85	.90	.94	.91	.920

POST HOC COMPARISONS

WF vs NF	*
OI vs FI	**
OI vs WF + NF	**
FI vs WF + NF	**

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TABLE B6. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (*: $p < .05$, **: $p < .01$) OF
POST HOC COMPARISONS FOR ALTITUDE ERROR (LOG x):
WIDE FOV TRAINING VS. EXPERIMENTAL GROUPS TRANSFER

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	.739	3	3.59	*
Trial Blocks (T)	1.2494	4	6.06	**
D x T	.6580	12	3.19	**
Error	.2061	289		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Wide FOV (WF)	1.89	1.92	1.75	1.79	2.09	1.888
Narrow FOV (NF)	1.75	1.74	1.89	1.74	1.62	1.754

POST HOC COMPARISON

WF vs NF

-

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TABLE B7. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR ALTITUDE VARIABILITY (σ (LOG x)): WIDE FOV TRAINING VS. EXPERIMENTAL GROUPS TRANSFER

ANOVA SUMMARY				
FACTOR	MEAN SQUARE	df	F	P
Display (D)	1.41603	3	24.41	**
Trial Blocks (T)	.28639	4	4.94	**
D x T	.08440	12	1.46	-
Error	.05800	289		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	2.03	2.02	2.04	2.09	2.00	2.036
Narrow FOV (NF)	1.78	1.79	1.74	1.61	1.70	1.724

POST HOC COMPARISON

WF VS NF

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TABLE B8. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (*: $p < .05$, **: $p < .01$) OF POST HOC COMPARISONS FOR LATERAL ERROR (LOG x): WIDE FOV TRAINING VS. EXPERIMENTAL GROUPS TRANSFER

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.75469	3	5.98	**
Trial Blocks (T)	.89897	4	3.06	*
D x T	.19002	12	.65	-
Error	.29349	289		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	1.96	1.89	1.75	1.86	1.76	1.844
Narrow FOV (NF)	1.72	1.63	1.51	1.62	1.46	1.588

POST HOC COMPARISON

WF vs NF

*

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TABLE B9. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR LATERAL VARIABILITY (σ (LOG x): WIDE FOV TRAINING VS. EXPERIMENTAL GROUPS TRANSFER

ANOVA SUMMARY				
FACTOR	MEAN SQUARE	df	F	P
Display (D)	1.39528	3	14.07	**
Trial Blocks (T)	1.74982	4	17.64	**
D x T	.15932	12	1.61	-
Error	.09918	289		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	2.12	2.01	1.89	1.96	1.76	1.948
Narrow FOV (NF)	1.78	1.65	1.54	1.57	1.63	1.634

POST HOC COMPARISON

WF VS NF ★★

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TABLE B10. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR ROLL VARIABILITY (σ (LOG x)): WIDE FOV TRAINING VS. EXPERIMENTAL GROUPS TRANSFER

ANOVA SUMMARY				
FACTOR	MEAN SQUARE	df	F	P
Display (D)	1.6096	3	30.4	**
Trial Blocks (T)	.37784	4	7.14	**
D x T	.01502	12	.28	-
Error	.05295	289		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	.92	.87	.79	.79	.78	.830
Narrow FOV (NF)	.65	.55	.50	.51	.53	.548

POST HOC COMPARISON

WF VS NF

★ ★

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TABLE B11. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR ALTITUDE ERROR (LOG x): COMBINED WIDE AND NARROW FOV TRAINING VS. OUTSIDE-IN AND FLIGHT-INSTRUMENTS TRANSFER

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.6043	2	7.18	**
Trial Blocks (T)	2.6791	4	12.0	**
D x T	.49203	8	2.2	*
Error	.22332	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Control (WF + NF)	2.02	2.0	1.83	1.82	1.84	1.902
Outside-In (OI)	2.16	1.80	1.49	1.57	1.27	1.658
Flight-Inst (FI)	2.20	1.86	1.74	1.47	1.75	1.804

POST HOC COMPARISONS

OI vs WF + NF	**
FI vs WF + NF	-

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TABLE B12. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR ALTITUDE VARIABILITY (σ (LOG x)): COMBINED WIDE AND NARROW FOV TRAINING VS. OUTSIDE-IN AND FLIGHT-INSTRUMENTS TRANSFER

ANOVA SUMMARY				
FACTOR	MEAN SQUARE	df	F	P
Display (D)	.3471	2	5.94	**
Trial Blocks (T)	.3917	4	6.70	**
D x T	.0940	8	1.61	-
Error	.0585	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK						
Group	1	2	3	4	5	Row Mean
Control (WF + NF)	2.04	2.06	1.99	2.02	1.98	2.018
Outside-In (OI)	2.09	1.89	1.84	1.85	1.85	1.904
Flight-Inst (FI)	2.17	2.06	1.90	1.83	1.95	1.982

POST HOC COMPARISONS

OI vs WF + NF	**
FI vs WF + NF	-

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TABLE B13. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR LATERAL ERROR (LOG x): COMBINED WIDE AND NARROW FOV TRAINING VS. OUTSIDE-IN AND FLIGHT-INSTRUMENTS TRANSFER

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	2.9082	2	11.07	**
Trial Blocks (T)	1.1348	4	4.32	**
D x T	.3019	8	1.15	-
Error	.2627	294		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Control (WF + NF)	2.00	1.96	1.72	1.80	1.75	1.846
Outside-In (OI)	1.72	1.33	1.50	1.47	1.54	1.512
Flight-Inst (FI)	2.10	1.72	1.44	1.70	1.79	1.750

POST HOC COMPARISONS

OI vs WF + NF	**
FI vs WF + NF	-

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TABLE B14. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR LATERAL VARIABILITY (σ (LOG x)): COMBINED WIDE AND NARROW FOV TRAINING VS. OUTSIDE-IN AND FLIGHT-INSTRUMENTS TRANSFER

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.0405	2	8.47	**
Trial Blocks (T)	2.5470	4	20.73	**
D x T	.0894	8	.73	-
Error	.1229	294		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Control (WF + NF)	2.21	2.02	1.90	1.86	1.78	1.954
Outside-In (OI)	2.13	1.78	1.66	1.61	1.61	1.758
Flight-Inst (FI)	2.27	1.93	1.80	1.57	1.71	1.856

POST HOC COMPARISONS

OI vs WF + NF	**
FI vs WF + NF	-

NAVTRAEQUIPCEN 78-C-0060-5

TABLE B15. ANOVA SUMMARY, (**: $p < .01$) AND OVERALL AND FOUR-TRIAL MEANS, FOR ROLL VARIABILITY (σ (LOG x)): COMBINED WIDE AND NARROW FOV TRAINING VS. OUTSIDE-IN AND FLIGHT-INSTRUMENTS TRANSFER

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	.1234	2	2.50	-
Trial Blocks (T)	.4074	4	8.26	**
D x T	.0246	8	.50	-
Error	.0494	294		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Control (WF + NF)	0.87	0.83	0.77	0.71	0.76	.788
Outside-In (OI)	1.00	0.85	0.81	0.81	0.81	.856
Flight-Inst (FI)	1.00	0.84	0.77	0.71	0.75	.814

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TABLE B16. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (*: $p < .05$, **: $p < .01$)
OF POST HOC COMPARISONS FOR ALTITUDE ERROR
(LOG x): TRANSFER DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.8883	3	7.04	**
Trial Blocks (T)	1.6909	4	6.3	**
D x T	.53724	12	2.0	*
Error	.26825	293		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	1.62	1.37	1.37	1.19	1.31	1.452
Narrow FOV (NF)	1.75	1.74	1.89	1.74	1.65	1.754
Outside-In (OI)	2.16	1.80	1.49	1.57	1.27	1.658
Flight Inst (FI)	2.20	1.86	1.74	1.47	1.75	1.804

POST HOC COMPARISONS

WF vs NF	**
WF vs OI	*
WF vs FI	**
NF vs OI	-
NF vs FI	-
OI vs FI	-

NAVTRAEQUIPCEN 78-C-0060-5

TABLE B17. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (*: $p < .05$, **: $p < .01$)
OF POST HOC COMPARISONS FOR ALTITUDE VARIABILITY
(σ (LOG x)): TRANSFER DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	.8831	3	14.25	**
Trial Blocks (T)	.4098	4	6.61	**
D x T	.0575	12	.93	-
Error	.0620	293		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Wide FOV (WF)	1.95	1.84	1.82	1.89	1.82	1.864
Narrow FOV (NF)	1.78	1.79	1.74	1.61	1.70	1.724
Outside-In (OI)	2.09	1.89	1.84	1.85	1.85	1.904
Flight Inst (FI)	2.17	2.06	1.90	1.83	1.95	1.982

POST HOC COMPARISONS

WF vs NF	**
WF vs OI	-
WF vs FI	*
NF vs OI	**
NF vs FI	**
OI vs FI	-

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TABLE B18. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (*: $p < .05$,) OF POST HOC COMPARISONS FOR LATERAL ERROR (LOG x): TRANSFER DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	.8257	3	3.10	*
Trial Blocks (T)	.6893	4	2.59	*
D x T	.2599	12	.98	-
Error	.2660	293		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Wide FOV (WF)	1.60	1.64	1.59	1.51	1.43	1.554
Narrow FOV (NF)	1.72	1.63	1.51	1.62	1.46	1.588
Outside-In (OI)	1.72	1.33	1.50	1.47	1.54	1.512
Flight Inst (FI)	2.10	1.72	1.44	1.70	1.79	1.750

POST HOC COMPARISONS

WF vs NF	-
WF vs OI	-
WF vs FI	*
NF vs OI	-
NF vs FI	-
OI vs FI	*

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TABLE B19. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS,
AND RELIABILITIES (*: $p < .05$, **: $p < .01$)
OF POST HOC COMPARISONS FOR LATERAL VARIABILITY
(σ (LOG x)): TRANSFER DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.0349	3	11.93	**
Trial Blocks (T)	1.6342	4	18.84	**
D x T	.1608	12	1.85	*
Error	.0868	293		

OVERALL AND FOUR-TRIAL MEANS

Group	TRIAL BLOCK					Row Mean
	1	2	3	4	5	
Wide FOV (WF)	1.77	1.57	1.57	1.60	1.51	1.604
Narrow FOV (NF)	1.78	1.65	1.54	1.57	1.63	1.634
Outside-In (OI)	2.13	1.78	1.66	1.61	1.61	1.758
Flight Inst (FI)	2.27	1.93	1.80	1.57	1.71	1.856

POST HOC COMPARISONS

WF vs NF	-
WF vs OI	**
WF vs FI	**
NF vs OI	**
NF vs FI	**
OI vs FI	*

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TABLE B20. ANOVA SUMMARY, OVERALL AND FOUR-TRIAL MEANS, AND RELIABILITIES (**: $p < .01$) OF POST HOC COMPARISONS FOR ROLL VARIABILITY (σ (LOG x)): TRANSFER DATA

FACTOR	ANOVA SUMMARY			
	MEAN SQUARE	df	F	P
Display (D)	1.5790	3	31.60	**
Trial Blocks (T)	.3174	4	6.35	**
D x T	.0325	12	.65	-
Error	.0500	293		

OVERALL AND FOUR-TRIAL MEANS

TRIAL BLOCK

Group	1	2	3	4	5	Row Mean
Wide FOV (WF)	.73	.59	.66	.69	.63	.660
Narrow FOV (NF)	.65	.55	.50	.51	.53	.548
Outside-In (OI)	1.00	.85	.81	.81	.81	.856
Flight Inst (FI)	1.00	.84	.77	.71	.75	.814

POST HOC COMPARISONS

WF vs NF	**
WF vs OI	**
WF vs FI	**
NF vs OI	**
NF vs FI	**
OI vs FI	-

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